

CERES Clouds Edition 4 Validation with C3M

Sunny Sun-Mack¹, Patrick Minnis², Yan Chen¹, Fu-Lung Chang¹, Qing Trepte¹, Patrick Heck³, Robert Arduini¹, Sharon Gibson¹, Rita Smith¹, Ricky Brown¹, Elizabeth Heckert¹, Seiji Kato² and Dave Winker²

(1) SSAI, Hampton, VA, USA

(2) NASA Langley Research Center, Hampton, VA

(3) CIMSS, Madison, WI, USA

Earth Radiation Budget Workshop 2012

22 – 25 October 2012

Geophysical Fluid Dynamics Laboratory (GFDL), Princeton, NJ



Objective

Validate global CERES cloud properties derived with passive remote sensing using similar parameters retrieved from lidar data



Outline

- **Data Product used**
- **Cloud Detection Comparison between CERES Ed4 and CALIPSO**
- **Cloud Top Height Comparisons Between CERES Ed4 and CALIPSO (Single Layer)**
- **Multilayer Detection Comparisons Between CERES Ed4 and CALIPSO**
- **Cloud Phase Comparisons Between CERES Ed4 and CALIPSO (Single Layer)**



Summary



DATA

- **C3M DATA is used**

A Langley NASA product merged with CALIPSO, CloudSat, CERES and MODIS. Contains cloud properties derived by CERES cloud retrieval with MODIS data for each MODIS 1km pixel, as well as CERES TOA radiative flux (SW, LW, and WN) for each CERES footprint.

- *update to Kato et al., JGR (2010)*

- **4 seasonal months: Jan. / April / July / Oct. 2008**



Cloud Detection Comparisons Between CERES Ed4 and CALIPSO



CALIPSO and CERES Cloud Detection Agreement (%)

January 2008 **Day Time** April 2008

CALIPSO CERES	Clear (33%)	Cloud (67%)
Clear (%)	83	14
Cloud (%)	17	86

CALIPSO CERES	Clear (34%)	Cloud (66%)
Clear (%)	77	12
Cloud (%)	23	88

July 2008

CALIPSO CERES	Clear (35%)	Cloud (65%)
Clear (%)	78	13
Cloud (%)	22	87

October 2008

CALIPSO CERES	Clear (26%)	Cloud (74%)
Clear (%)	72	11
Cloud (%)	28	89



CERES classifies correctly 85% (Jan), 84% (April), 84% (July) and 85% (Oct) of all pixels wrt CALIPSO

CALIPSO and CERES Cloud Detection Agreement (%)

January 2008 **Night Time** April 2008

CALIPSO CERES	Clear (28%)	Cloud (72%)
Clear (%)	78	18
Cloud (%)	22	82

CALIPSO CERES	Clear (28%)	Cloud (72%)
Clear (%)	77	13
Cloud (%)	23	87

July 2008

CALIPSO CERES	Clear (30%)	Cloud (70%)
Clear (%)	78	17
Cloud (%)	22	83

October 2008

CALIPSO CERES	Clear (21%)	Cloud (79%)
Clear (%)	70	16
Cloud (%)	30	84



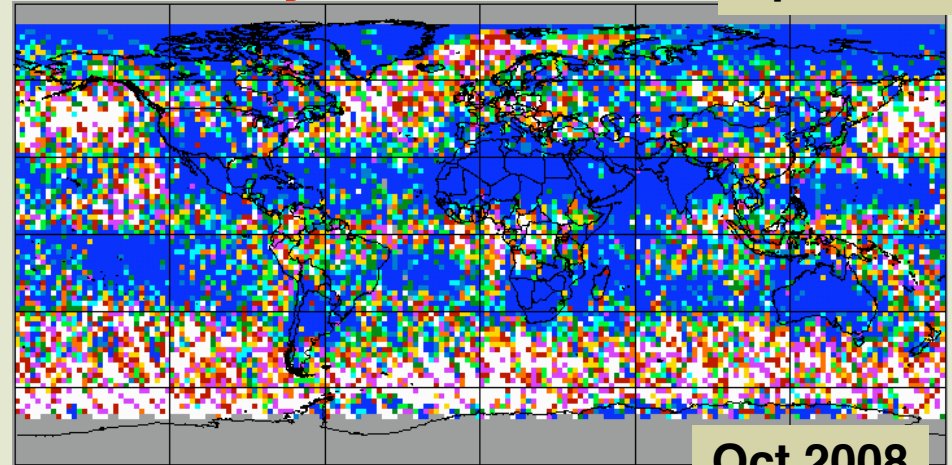
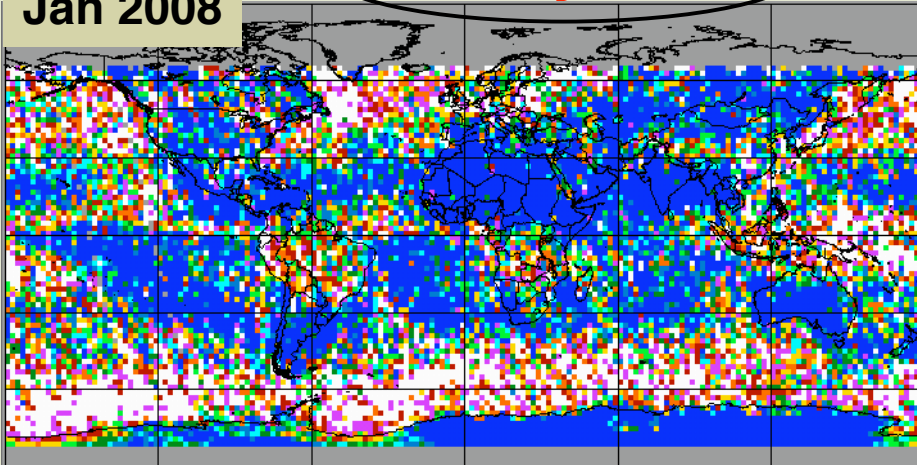
CERES classifies correctly 81% (Jan), 84% (April), 81% (July) and 81% (Oct) of all pixels wrt CALIPSO

DayTime

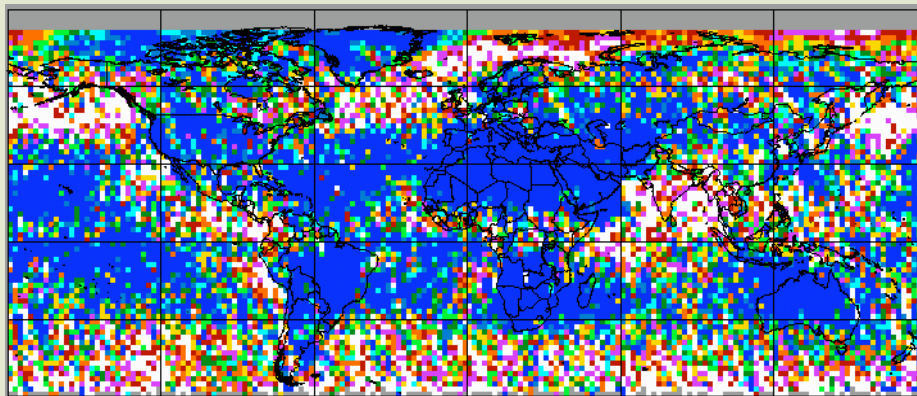
CERES Ed4 Cloud Fraction for all Cloudy Pixels Determined by CALIPSO

Apr 2008

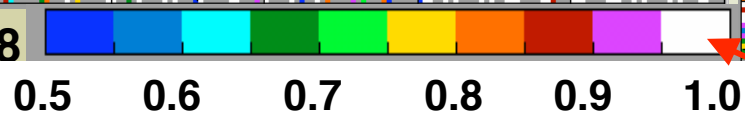
Jan 2008



Oct 2008



July 2008



CALIPSO CF = 1

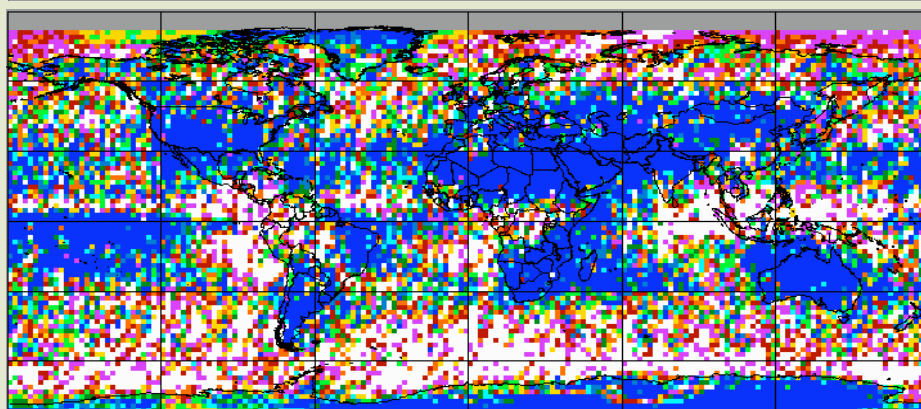
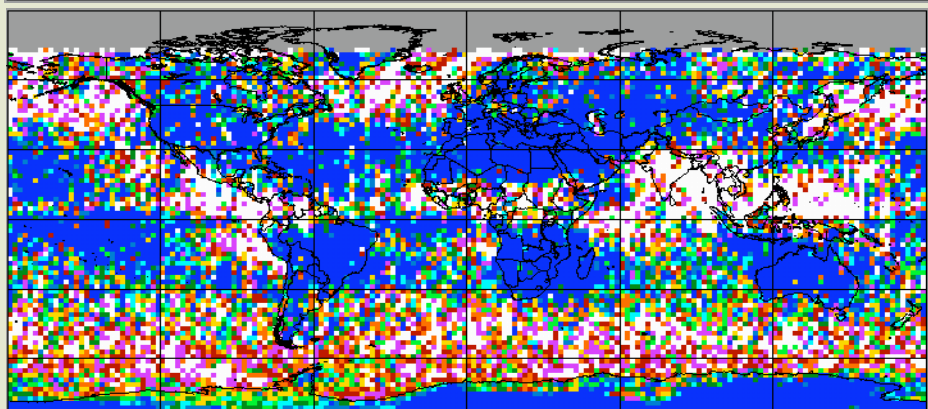
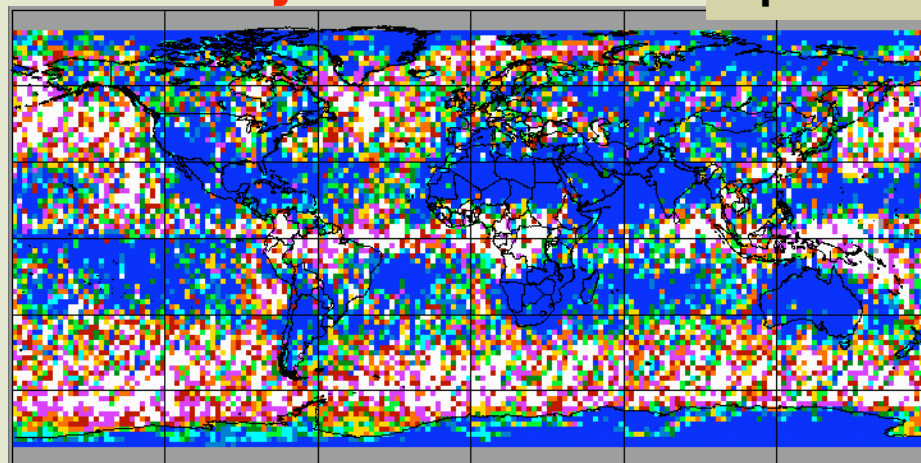
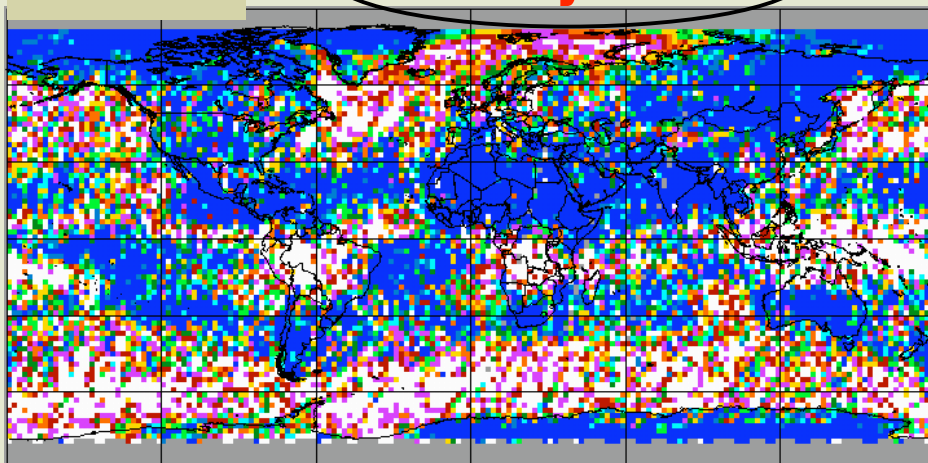
- CERES Ed4 agrees well with CALIPSO in both NH and SH mid-latitude oceans
- CERES calls cloudy pixels clear ~ 40% of times over tropical oceans
- CERES under-detect clouds over most lands, Arctic Ocean in April, Antarctica in Jan by 50%,

Night Time

CERES Ed4 Cloud Fraction for all Cloudy Pixels Determined by CALIPSO

Jan 2008

Apr 2008



July 2008

Oct 2008

0.5 0.6 0.7 0.8 0.9 1.0

CALIPSO CF = 1

- CERES Ed4 agrees well with CALIPSO in both NH and SH mid-latitude oceans
- CERES calls cloudy pixels clear ~ 40% of times over tropical oceans
- CERES under-detect clouds over most lands, Antarctica by 50%

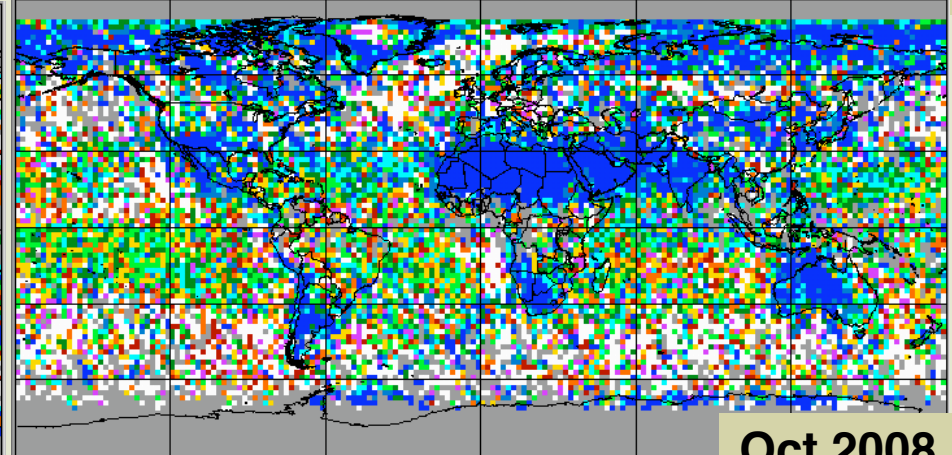
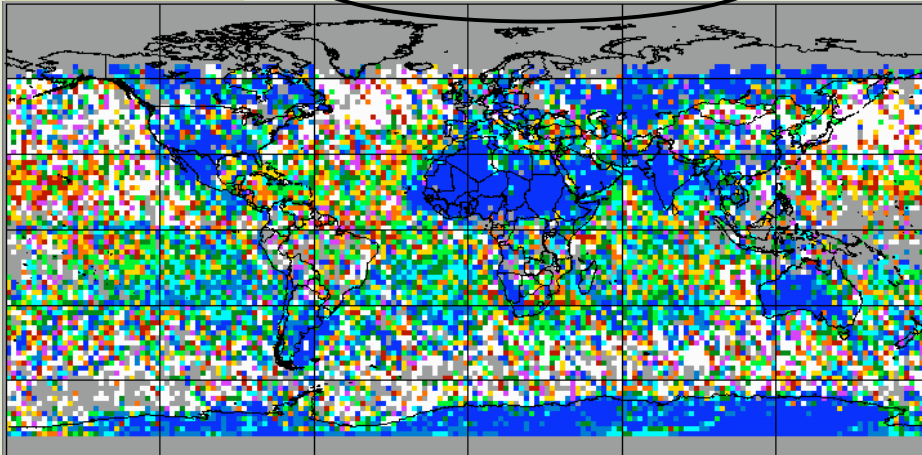


Day Time

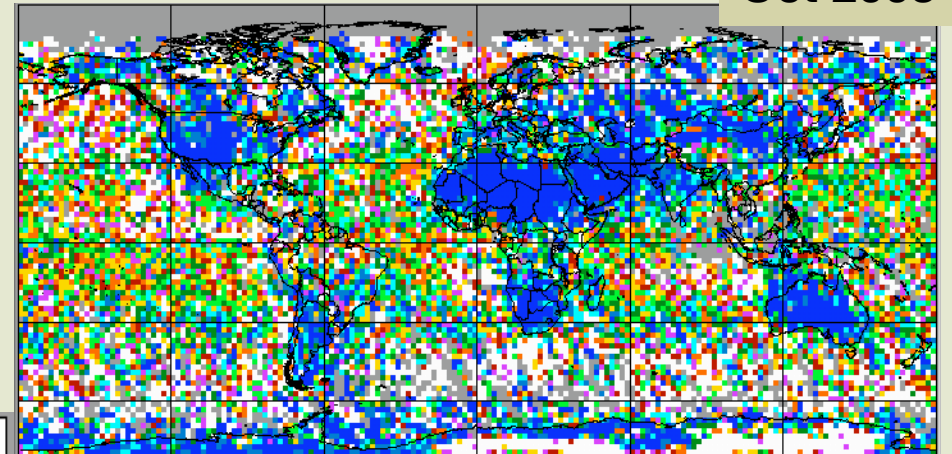
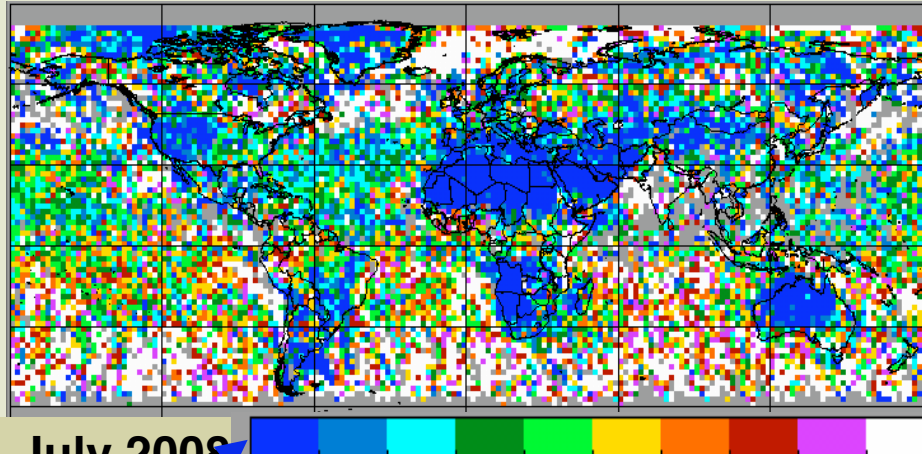
**CERES Ed4 Cloud Fraction for all
Clear Pixels Determined by CALIPSO**

Jan 2008

Apr 2008



Oct 2008



July 2008

0.0 0.1 0.2 0.3 0.4 0.5

CALIPSO CF = 0

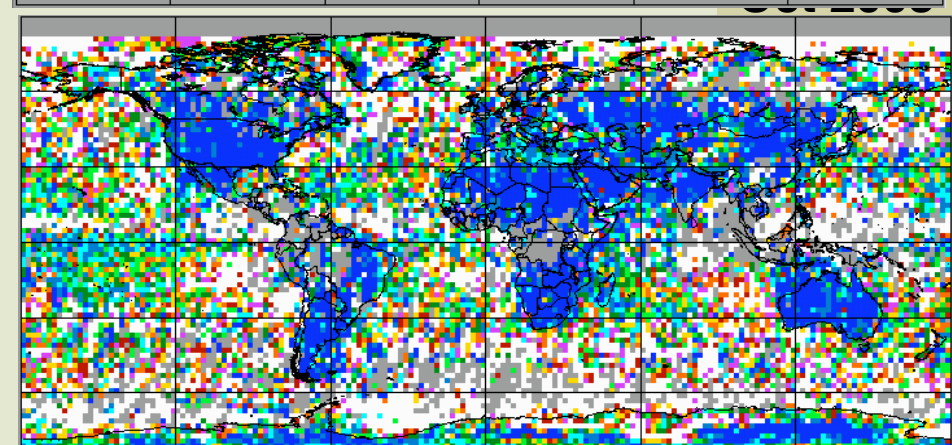
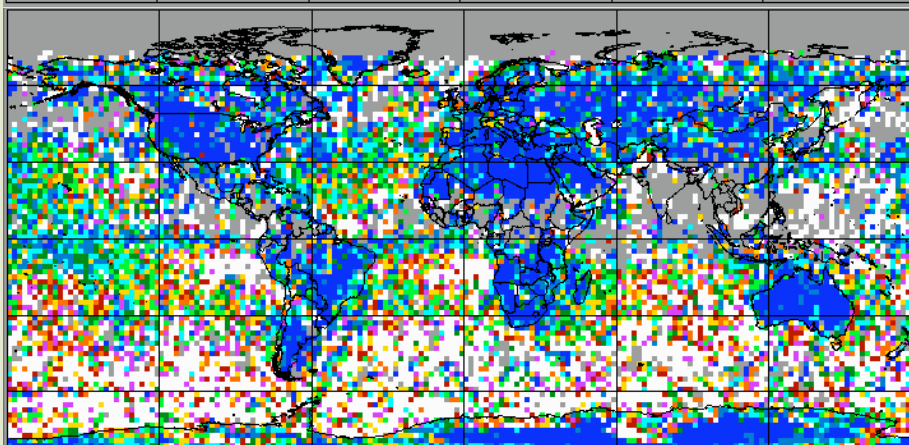
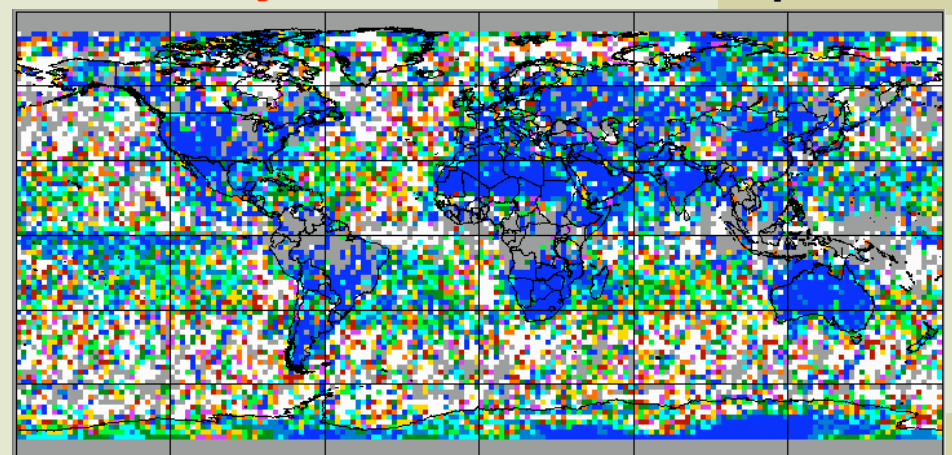
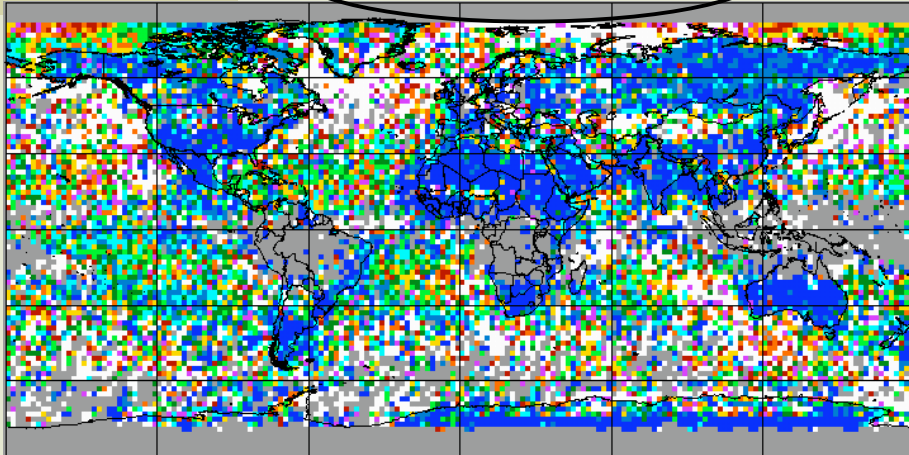
- The areas, where CERES Ed4 did well when cloudy, over estimate clouds
- The area, where CERES under-estimate clouds (lands..) when cloudy, agree CALIPSO
- CERES under-detect clouds over most lands by 50%

Night Time

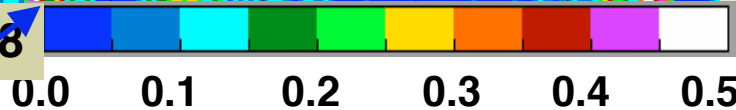
CERES Ed4 Cloud Fraction for all Clear Pixels Determined by CALIPSO

Jan 2008

Apr 2008



July 2008



CALIPSO CF = 0

- Areas where CERES Ed4 did well when cloudy, overestimate clouds
- Areas where CERES underestimate clouds (land..) when cloudy, agree w CALIPSO
- CERES under-detects clouds over most land by 50%



Cloud Detection Summary

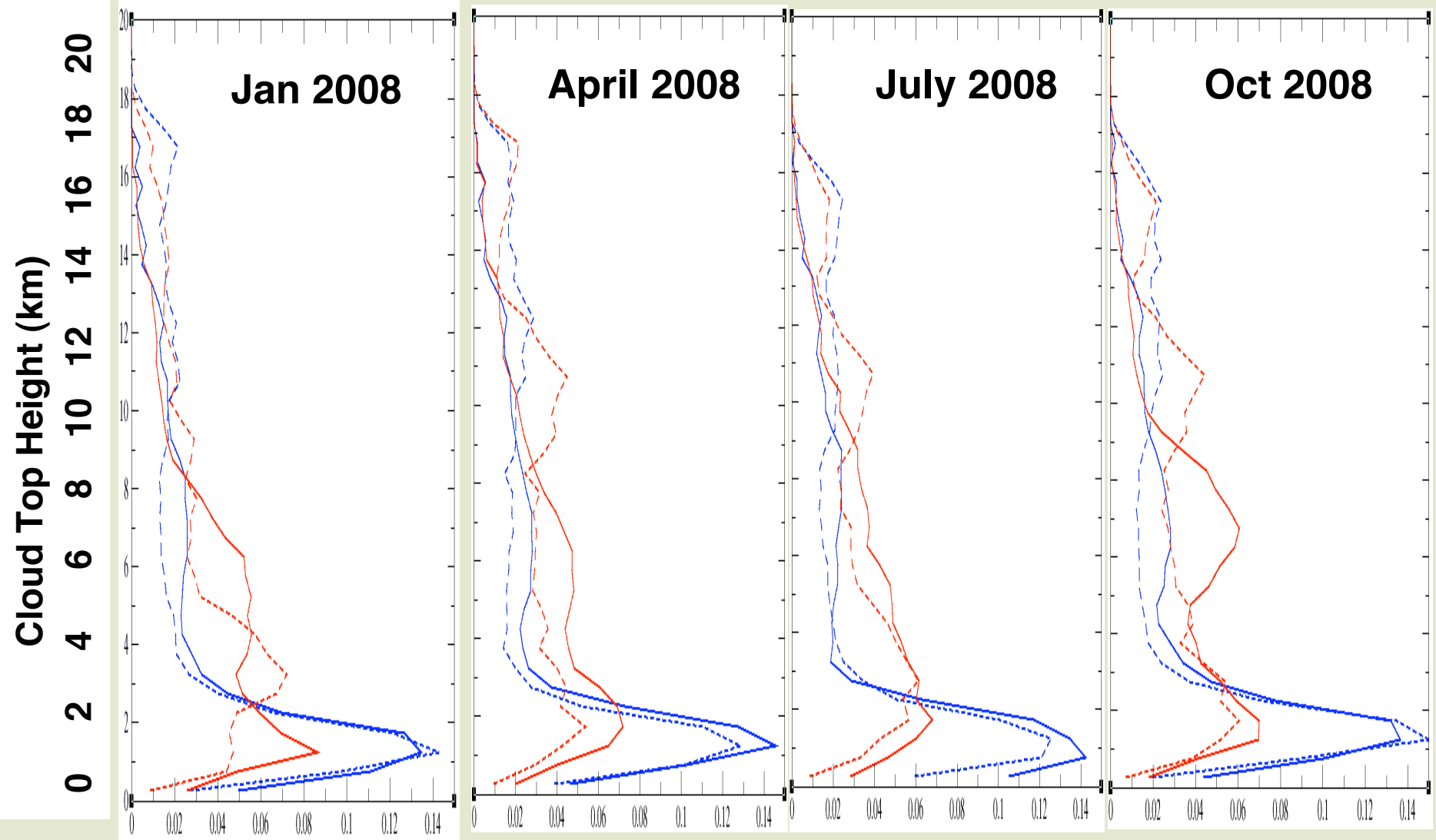
- Where CERES Ed4 compares well with CALIPSO when cloudy, CERES tends to overestimate clouds when clear (mid-latitude oceans...)
- Where CERES Ed4 compares well with CALIPSO when clear, underestimate clouds when cloudy (most land areas...)
- Polar cloud detection agreement / disagreement mixed, depends on season
- Instantaneous disagreements tend to cancel each other, leaving a small underestimate of total cloud cover overall
- In all mismatch conditions, we need to
 - *use case studies to determine source of the discrepancies,*
 - *determine aerosol environment*
 - *compute optical depth & height pdfs of missed clouds*



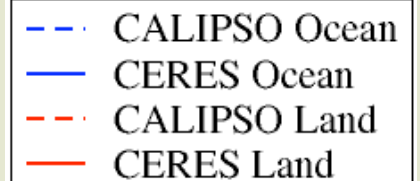
Cloud Top Height Comparisons Between CERES Ed4 and CALIPSO (Single Layer)



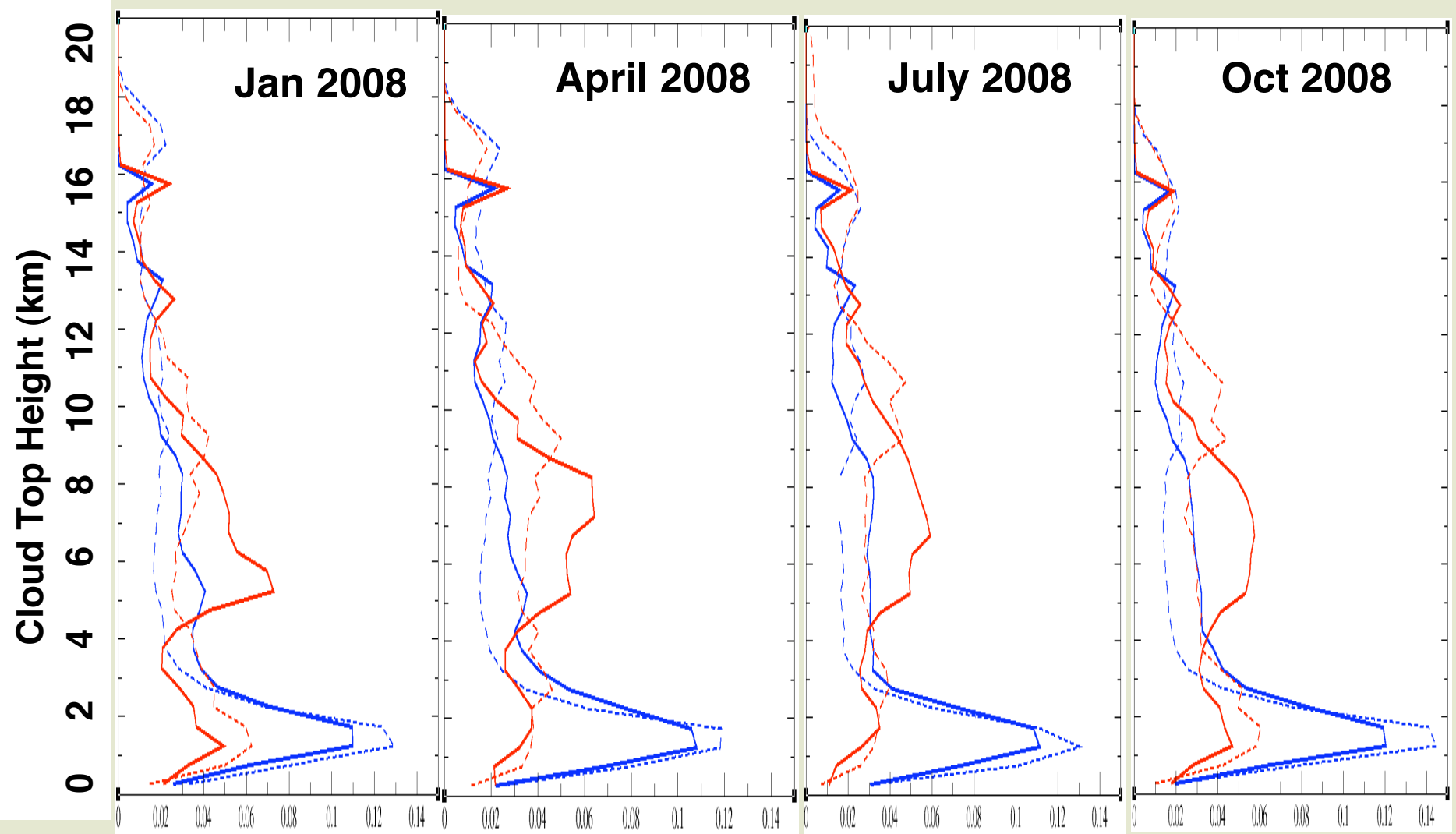
Cloud Top Height Histogram, **Single Layer, Day Time**



- CERES low clouds agree well w/ CALIPSO, but Jan land, snow?
- High clouds too low, peaks at 11 and 16 km missed
 - primarily optically thin clouds



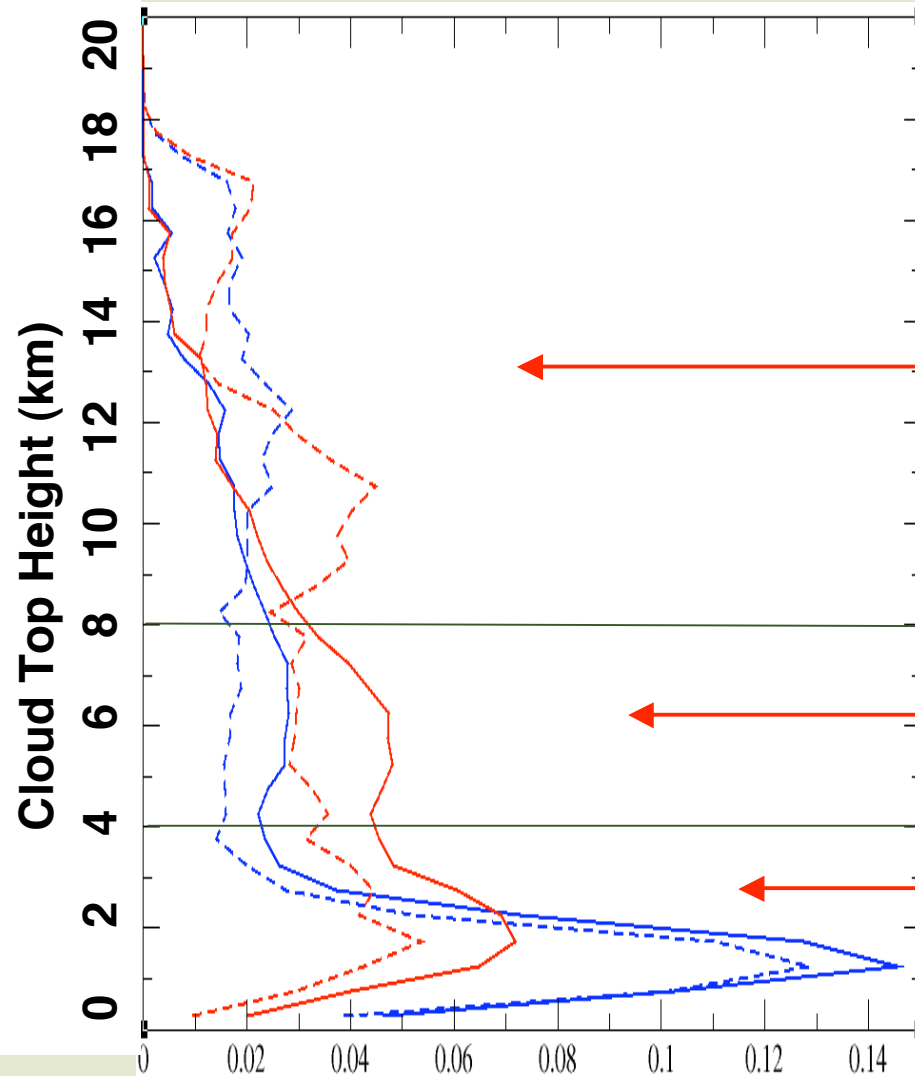
Cloud Top Height Histogram, **Single Layer, Night Time**



- CERES low clouds agree well with CALIPSO overall
- CERES middle clouds too low, ~ 3 km too low
- CERES high clouds cutoff at ~16 km, default to tropic tropopause

--- CALIPSO Ocean
— CERES Ocean
--- CALIPSO Land
— CERES Land

Divide Cloud Heights into Low, Mid and High



High Level Clouds
(8 - 20 km)

Mid Level Clouds
(4 - 8 km)

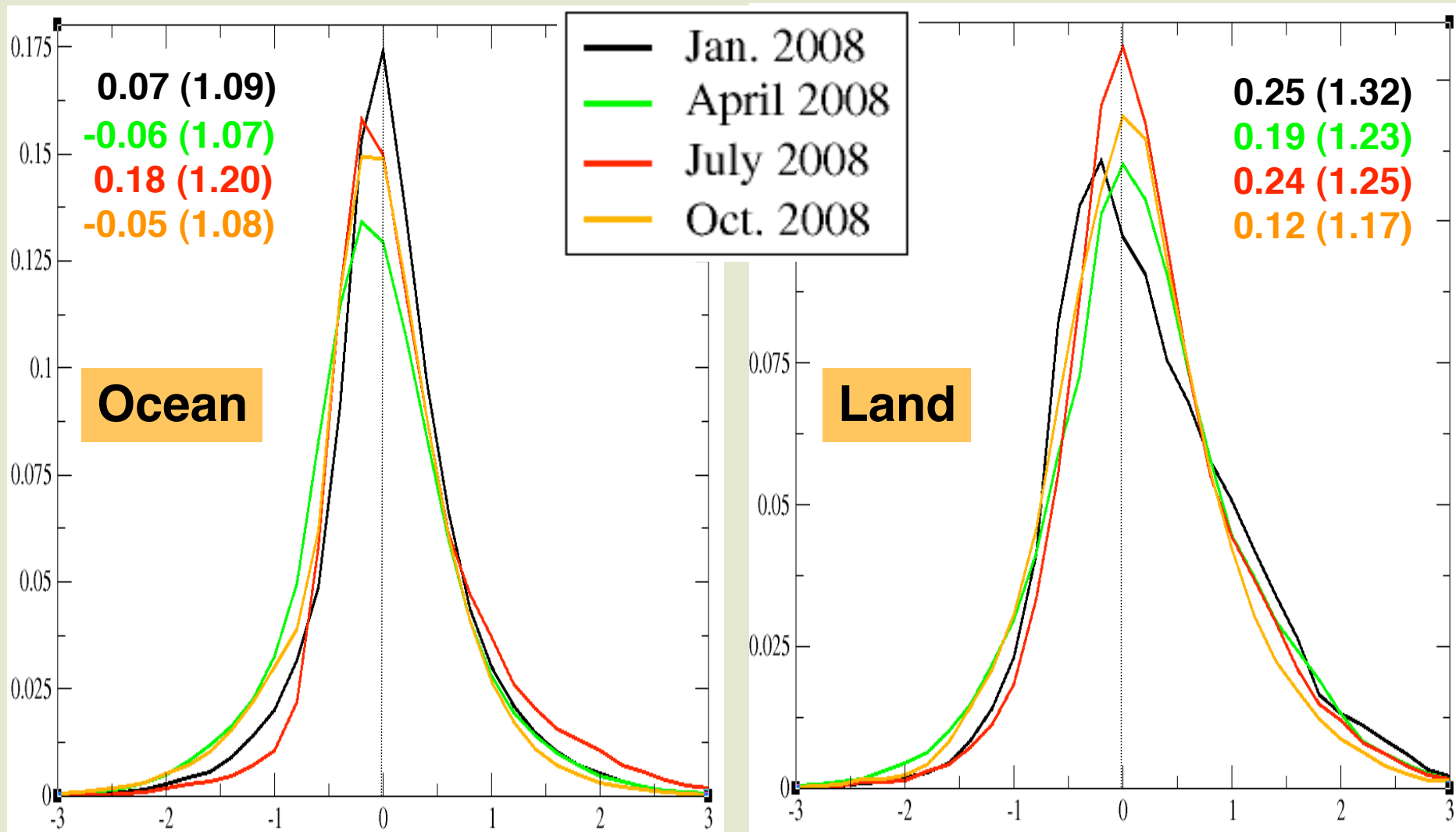
Low Level Clouds
(0 - 4 km)

--- CALIPSO Ocean
— CERES Ocean
--- CALIPSO Land
— CERES Land



Low Level Clouds Day Time

Histograms of Cloud Top Height Difference

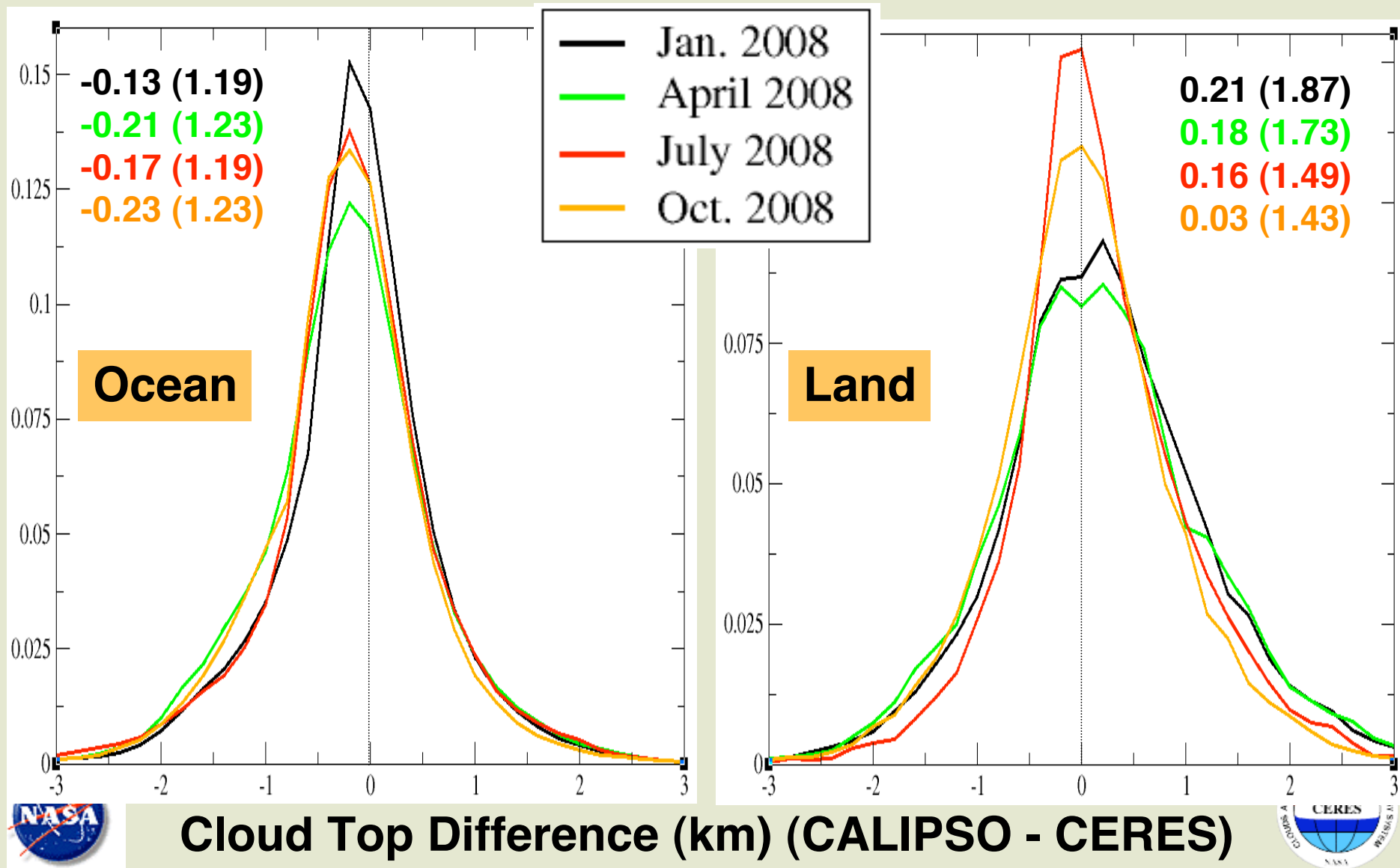


Cloud Top Difference (km) (CALIPSO - CERES)



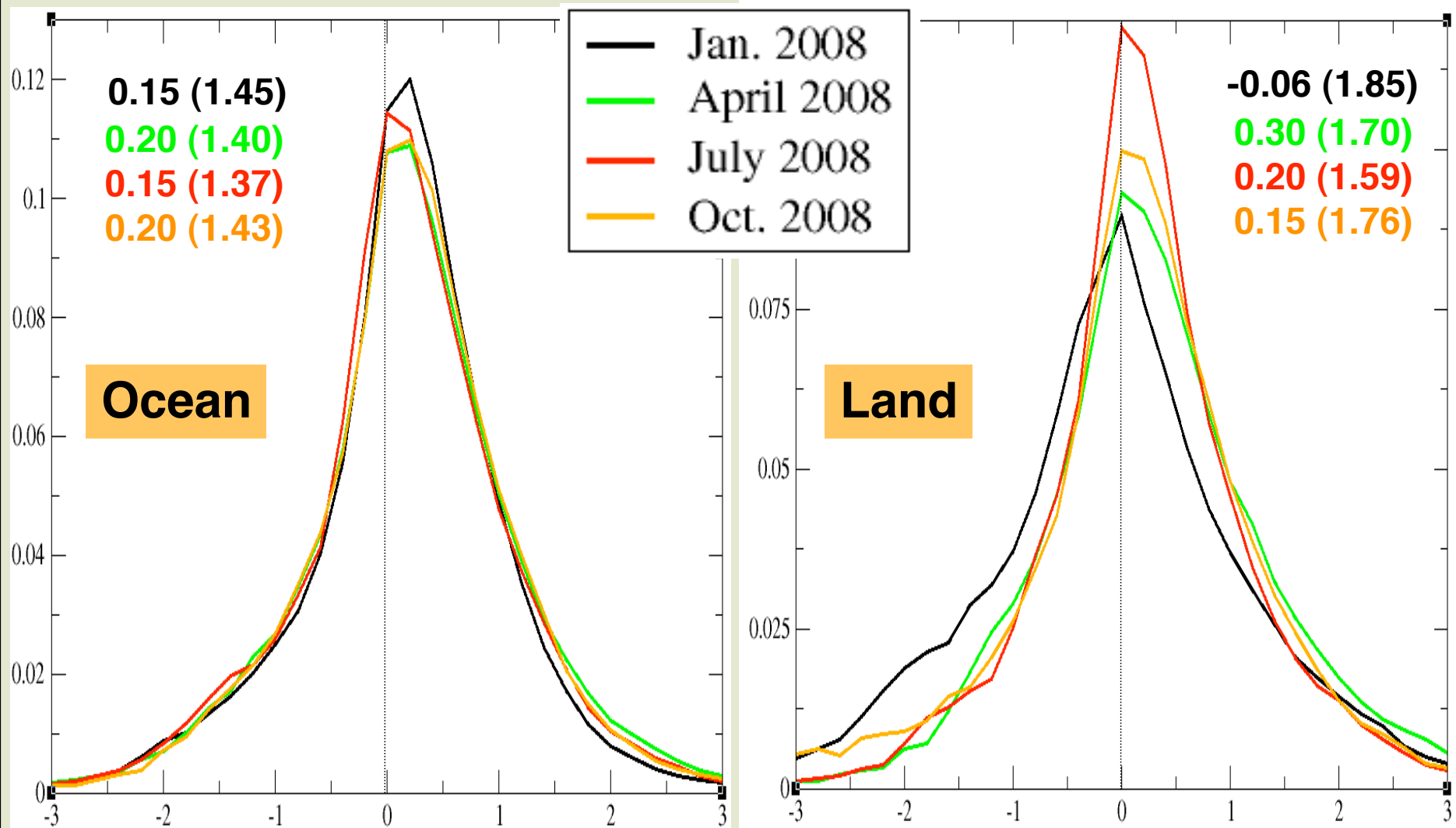
Low Level Clouds Night Time

Histograms of Cloud Top Height Difference



Mid Level Clouds Day Time

Histograms of Cloud Top Height Difference

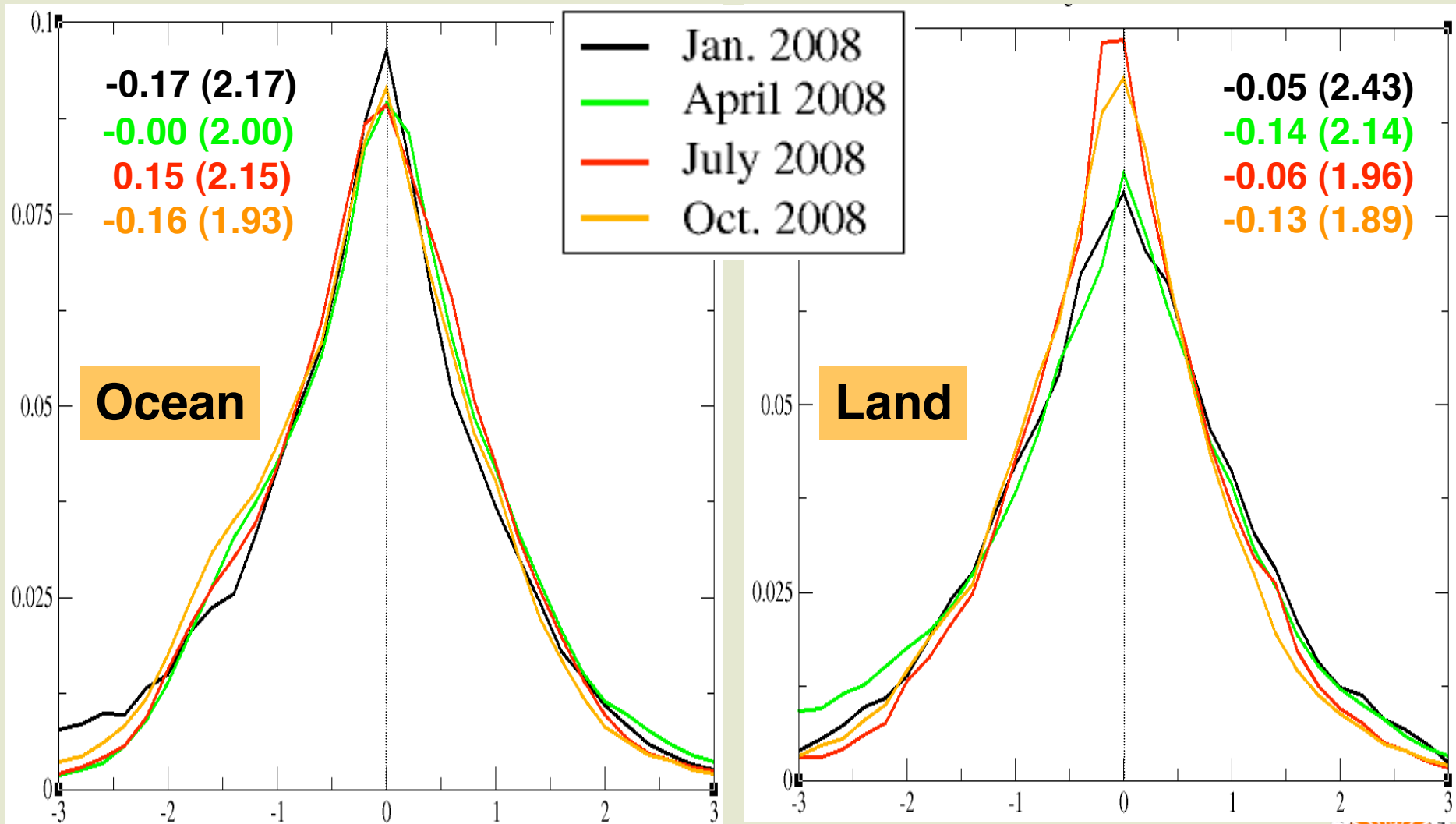


Cloud Top Difference (km) (CALIPSO - CERES)



Mid Level Clouds Night Time

Histograms of Cloud Top Height Difference



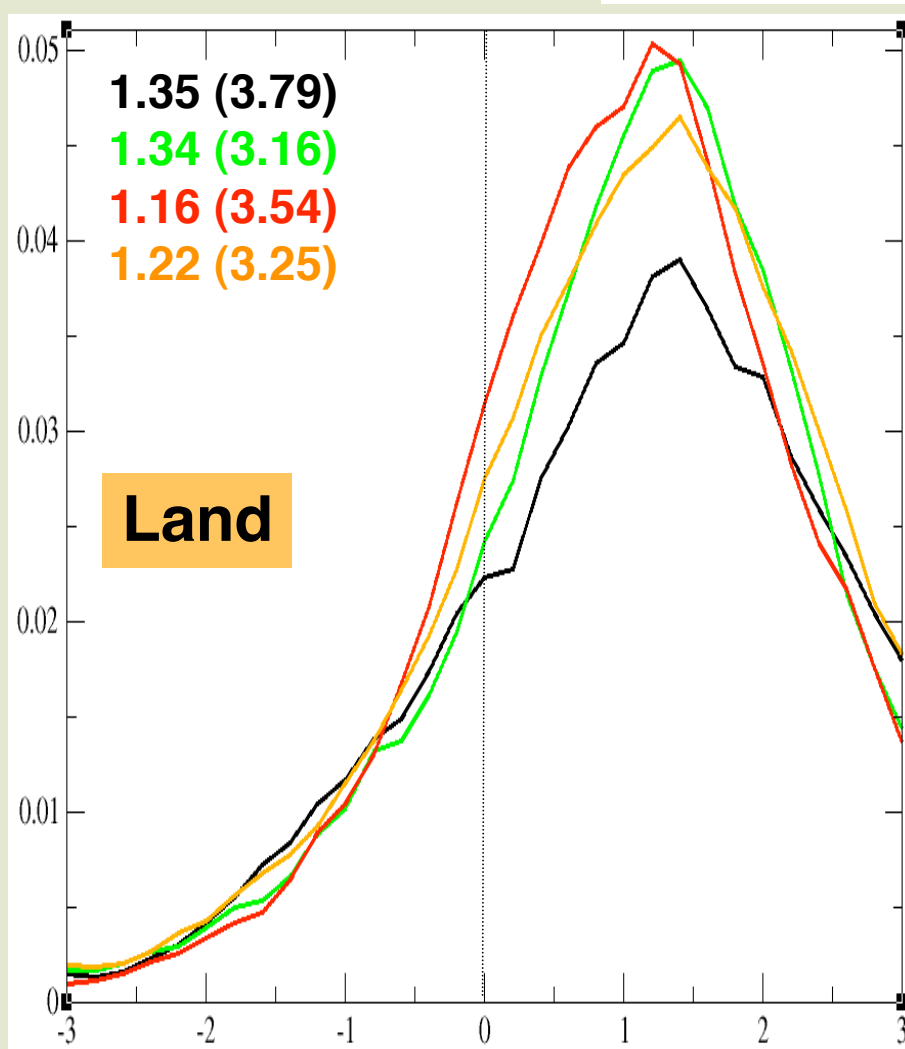
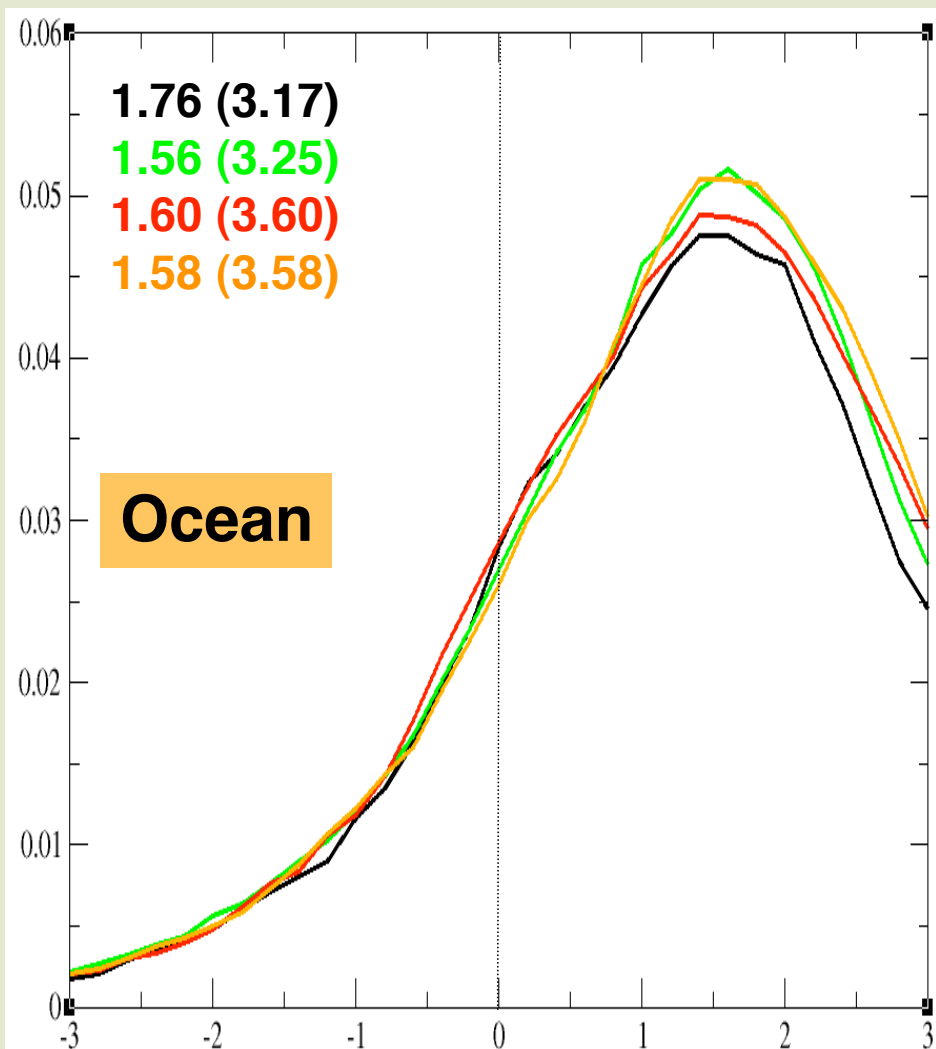
Cloud Top Difference (km) (CALIPSO - CERES)



High Level Clouds Day Time

Histograms of Cloud Top Height Difference

— Jan. 2008
— April 2008
— July 2008
— Oct. 2008



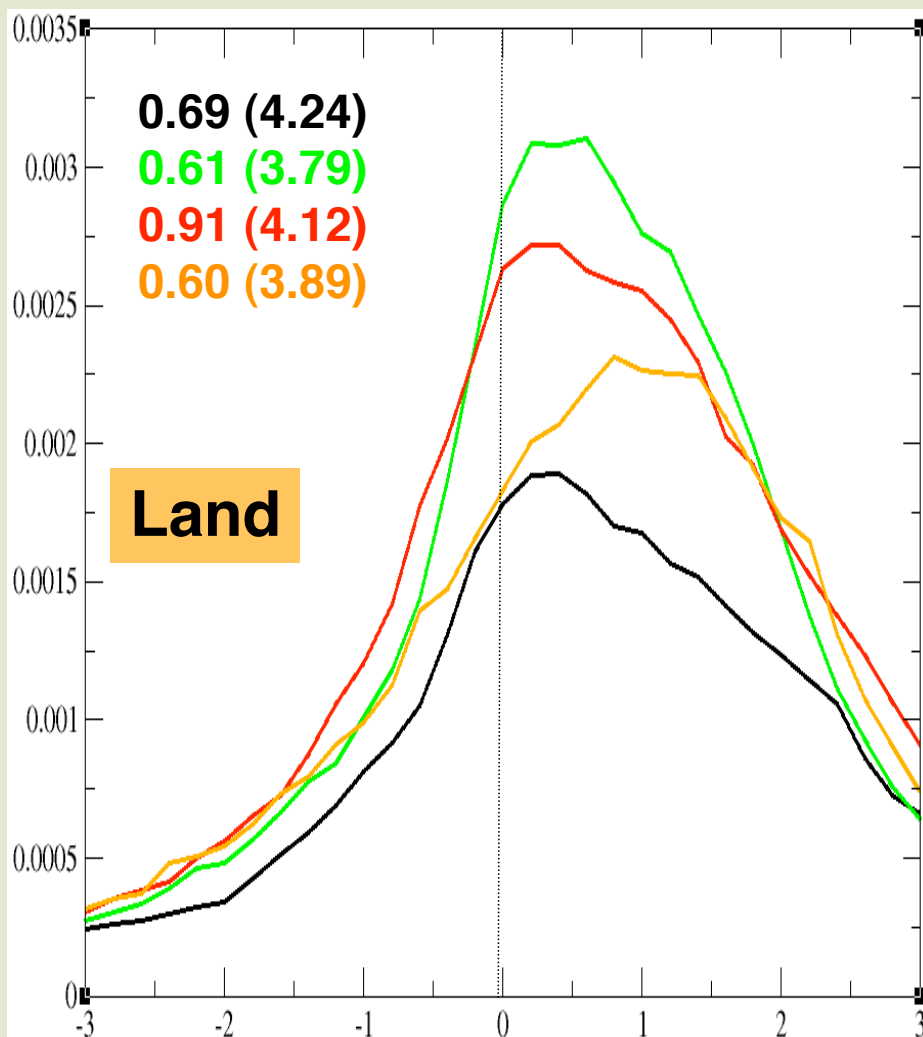
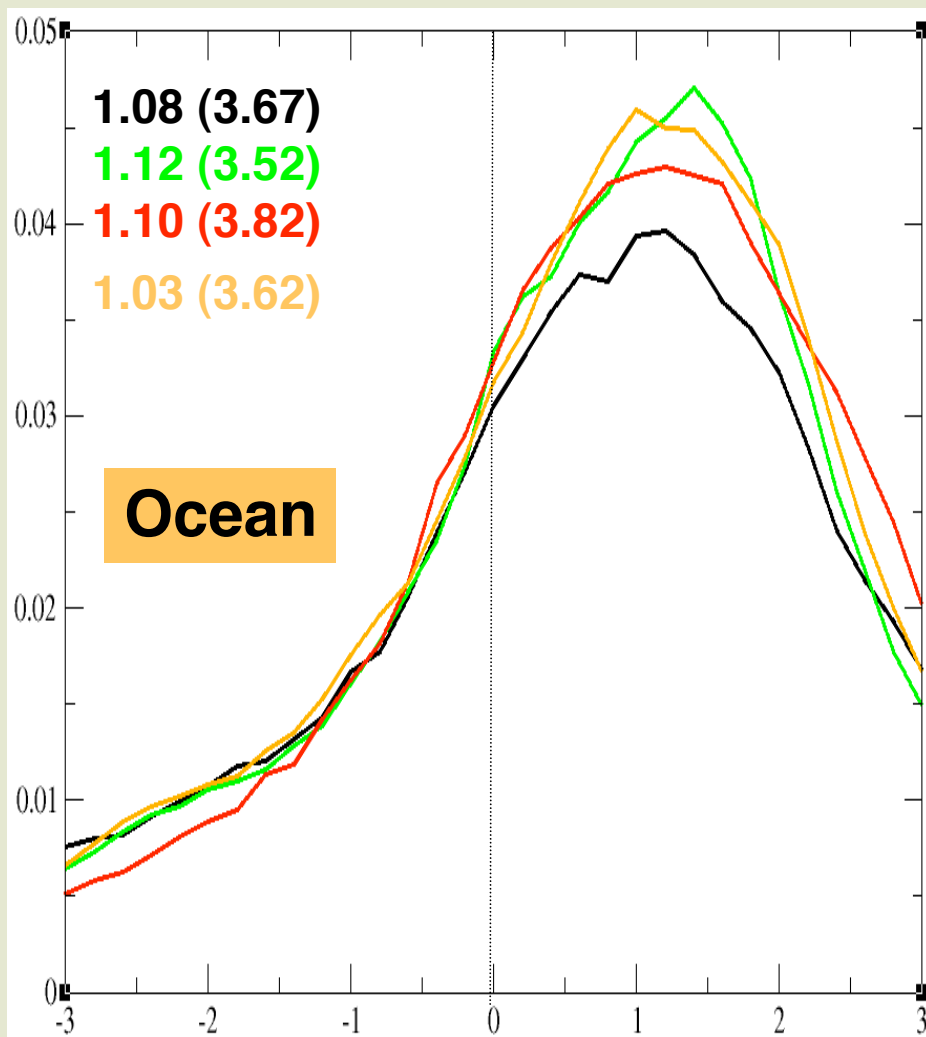
Cloud Top Difference (km) (CALIPSO - CERES)



High Level Clouds Night Time

Histograms of Cloud Top Height Difference

— Jan. 2008
— April 2008
— July 2008
— Oct. 2008



Cloud Top Difference (km) (CALIPSO - CERES)



Single-layer Cloud Height Summary

- Mean low-level cloud heights generally differ from CALIPSO by < 0.2 km
 - *Instantaneous error ~ 1.1 km over ocean, 1.2 km over land
a little worse ($+0.2$ km) at night*
- Mean mid-level cloud heights generally differ from CALIPSO by < 0.2 km
 - too low during day, too high at night
 - *Instantaneous error ~ 1.4 km over ocean, 1.7 km over land
worse (2.0 km) at night*
- Mean high cloud heights generally too low
 - day: 1.6 ± 3.3 km (ocean), 1.3 ± 3.4 km (land)
 - night: 1.1 ± 3.7 km (ocean), 0.7 ± 4.0 km (land)
 - *differences likely due to optically thin clouds (will be verified)*

*better night mean due to use of IR method,
CO2 helps some during day, but VIS asymmetry factor still too low*
- Disagreement between VIS and IR optical depths remains a fundamental problem for remote sensing & may have implications for broadband



Multilayer Detection Comparisons Between CERES Ed4 and CALIPSO



CALIPSO and CERES Single/Multi Detection Agreement (%)

Day Time

January 2008

April 2008

CALIPSO CERES	Clear (33%)	Single (40%)	Multi (27%)
Clear	28	7	3
Single	5	29	18
Multi	0	4	6

CALIPSO CERES	Clear (34%)	Single (39%)	Multi (27%)
Clear	26	5	2
Single	8	29	19
Multi	0	4	5

July 2008

October 2008

CALIPSO CERES	Clear (35%)	Single (40%)	Multi (25%)
Clear	27	6	2
Single	7	30	17
Multi	0	3	5

CALIPSO CERES	Clear (26%)	Single (36%)	Multi (38%)
Clear	19	4	4
Single	7	29	32
Multi	0	2	2

CERES detects only 22% (Jan), 19%(April), 20%(July) and 5% (Oct) of all ML pixels

- different definitions
- some CERES ML clouds actually contiguous water/ice clouds



CALIPSO and CERES Single/Multi Detection Agreement (%)

Night Time

January 2008

April 2008

CALIPSO CERES	Clear (28%)	Single (40%)	Multi (32%)
Clear	22	8	5
Single	6	29	23
Multi	0	3	4

CALIPSO CERES	Clear (28%)	Single (40%)	Multi (31%)
Clear	22	6	3
Single	7	31	24
Multi	0	3	3

July 2008

October 2008

CALIPSO CERES	Clear (30%)	Single (39%)	Multi (31%)
Clear	24	7	4
Single	7	29	23
Multi	0	3	3

CALIPSO CERES	Clear (21%)	Single (38%)	Multi (41%)
Clear	15	6	6
Single	6	30	34
Multi	0	2	1

CERES detects only 13% (Jan), 10%(April), 10%(July) and 2% (Oct) of all ML pixels

- different definitions
- some CERES ML clouds actually contiguous water/ice clouds



Cloud Phase Comparisons Between CERES Ed4 and CALIPSO (Single Layer)



CALIPSO and CERES Single Layer Cloud Phase Agreement (%)

Average of Jan, April, July and Oct, 2008

Day Time, Ocean

CALIPSO CERES	Water (51%)	Ice (39%)	No Ret (10%)
Water	92	15	52
Ice	5	67	10
No Ret	0	0	0
Clear	3	18	38

Day Time, Land

CALIPSO CERES	Water (34%)	Ice (53%)	No Ret (14%)
Water	79	15	31
Ice	10	52	11
No Ret	1	3	2
Clear	10	30	56

Night Time, Ocean

CALIPSO CERES	Water (52%)	Ice (41%)	No Ret (7%)
Water	80	18	44
Ice	16	65	20
No Ret	0	0	0
Clear	4	17	36

Night Time, Land

CALIPSO CERES	Water (28%)	Ice (62%)	No Ret (10%)
Water	49	6	13
Ice	33	58	16
No Ret	0	0	0
Clear	18	36	71

- CERES water phase agrees well with CALIPSO, 92% (day) & 80% (night) over ocean
- CERES ice phase agrees with CALIPSO ~50-65%, due to missing ice cloud detection